AD NUMBER

ADB200116

NEW LIMITATION CHANGE

TO

Approved for public release, distribution unlimited

FROM

Distribution authorized to DoD only. Other requests shall be referred to Embassy of Australia, Attn: Head. Pub. Sec. Def./Sci., 1601 Massachusetts Ave., NW, Washington, DC 20036.

AUTHORITY

DSTRO ltr, 26 Mar 2002

DSTO

AR-009-239

DSTO-GD-0047

The Effect of Small Ground Planes on 9mm Conical Monopole D-Dot Sensor Response

Sean Braidwood and Geoff Staines

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

The Effect of Small Ground Planes on 9 mm Conical Monopole D-Dot Sensor Response

Sean Braidwood and Geoff Staines

Electronic Warfare Division
Electronics and Surveillance Research Laboratory

DSTO-GD-0047

ABSTRACT

The effect of small ground planes on the response of a 9 mm conical monopole electric field sensor was studied experimentally for fields incident from various angles to the ground plane. This short study was undertaken to investigate the consequences of ground plane diffraction for 200 mm, 400 mm, and 600 mm diameter ground planes. These diameters are typical of those used for practical measurements. Qualitative assessments are made of the effects on the shape and amplitude of the measured pulse and the implications for practical electric field measurements.

DOD ONly

RELEASE LIMITATION

Access additional to the initial distribution list is limited to the Defence Organisation of Australia, USA, UK. Others MUST be referred to Chief, Electronic Warfare Division, ESRL.

DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

Published by

DSTO Electronics and Surveillance Research Laboratory
PO Box 1500
Salisbury South Australia 5108

Telephone: (08) 259 5181
Fax: (08) 259 5938

AR-009-239
March 1995

Conditions of Release and Disposal

The Effect of Small Ground Planes on 9 mm Conical Monopole D-Dot Sensor Response

EXECUTIVE SUMMARY

The effect of small ground planes on the response of a 9 mm conical monopole electric field sensor is studied experimentally. These field sensors are used extensively in the DSTO Wideband Test Facility for measuring ultrawideband fields scattered from or coupled into targets of military interest. For most applications, the field probes are either mounted on a very large ground plane or are aligned so that the incident field is normal to the ground plane of the probe. In both these instances diffractive effects from the edge of the ground plane are negligible. However, occasionally fields with arbitrary angles of incidence must be measured using field sensors mounted on small ground planes. In this short study, diffractive effects of small ground planes on the field sensor response are assessed qualitatively, together with the implications for practical measurements.

THIS PAGE INTENTIONALLY BLANK

Authors

Sean Braidwood
Electronic Warfare Division

Sean Braidwood received the BSc.(Hons) from Adelaide University in 1989 and a MSc. in atomic physics from Flinders University in 1993. He is currently working for Advanced Concepts Group in Electronic Warfare Division, DSTO Salisbury.

Geoff Staines
Electronic Warfare Division

Geoff Staines received the BSc. (Physics) degree from the University of Queensland in 1987, the BSc.(Hons) from Flinders University in 1988 and a PhD. in plasma physics from Flinders University in 1991. Since 1992 he has been a research scientist in Advanced Concepts Group, Electronic Warfare Division, DSTO Salisbury.

THIS PAGE INTENTIONALLY BLANK

Contents

THIS PAGE INTENTIONALLY BLANK

1. Introduction

The conical D-dot sensor described by Parkes and Smith [1] and shown in Figure 1.1 is used for transient electromagnetic field measurements in the DSTO Wideband Test Facility. Ideally, the sensor is mounted on an infinite ground plane, and its characteristics for this case have been studied extensively by Staines and Braidwood [2].

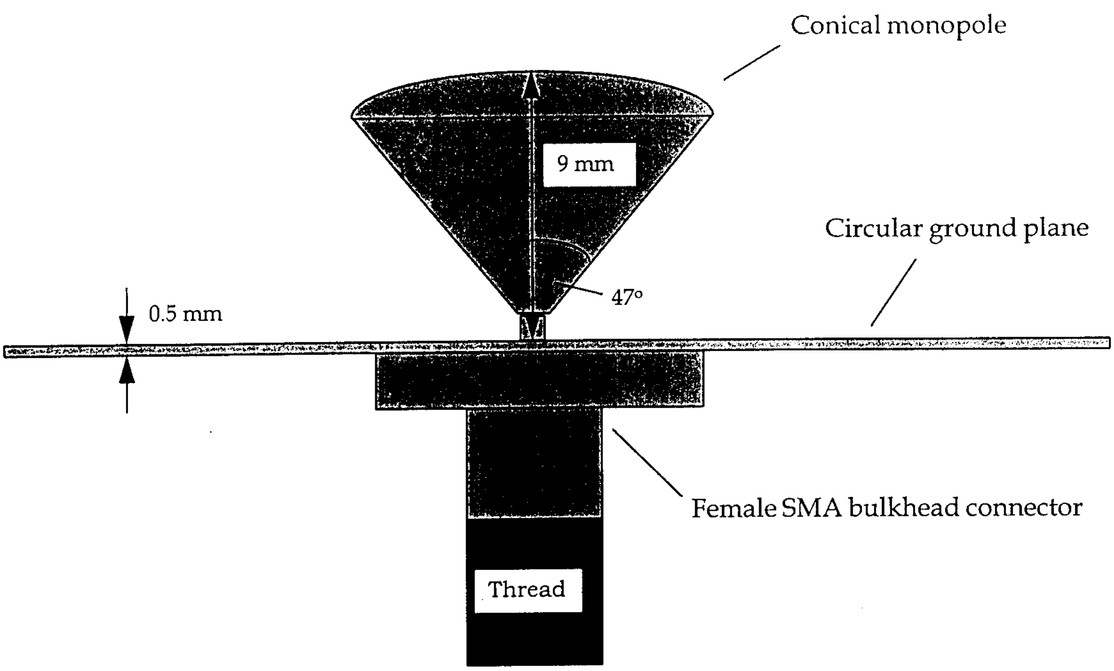

Figure 1.1: Conical D-dot sensor.

For most of the experiments planned for the Wideband Test Facility, the D-dot sensors will be mounted on a large ground plane 10 m long and 6 m wide which is infinite for practical purposes. Where small ground planes must be used with these sensors, the electric field will be approximately normal to the ground plane. In both of these situations, diffraction from the edge of the ground plane will be negligible.

However, there are occasional uses for D-dot sensors mounted on small ground planes where the electric field will not in general be normal to the ground plane. Field measurements inside irregular cavities are a typical example. The objective of this short empirical study was to observe the effect of three different sized ground planes on the response of a 9 mm conical D-dot probe when measuring fields with arbitrary angles of incidence. This was done by illuminating the D-dot sensor, with a number of different sized ground planes attached, with a 150 ps ultrawideband (UWB) pulse at a range of approximately 10 m. The effect of the finite ground plane on the response of the D-dot sensor for various angles of incidence of the electric field was measured.

The outcome of this study was insight into the validity of the field measurements obtained using small ground planes. In terms of the DSTO programme, the limited use of D-dot sensors on small ground planes for electric fields not perpendicular to the ground plane did not justify theoretical or more detailed experimental investigation.

2. Finite ground plane experiments

2.1 Experimental setup

A schematic diagram of the experimental setup is shown in Figure 2.1. As can be seen a 9 mm conical D-dot sensor mounted on a finite ground plane was placed approximately 10 m on boresight from a UK DRA designed TEM "kipper" antenna. Along axis these antennas have been shown to radiate an electric far-field proportional to the derivative of the driving pulse waveform [1].

Three different circular ground planes with diameters of 200 mm, 400 mm and 600 mm were used with the sensor. In the case of the 200 mm and 400 mm ground planes both the sensor and antenna were positioned atop masts approximately 4 m above ground level. Due to the excessive weight of the 600 mm ground plane the sensor had to be fixed on a tripod only 1 m above the ground with the antenna likewise positioned.

A Kentech HMP1 pulse generator was used as the source for the antenna. This unit produced a 3.5 kV, 100 ps rise time step pulse. Figure 2.2 shows the output voltage waveform from the source. It was triggered externally using a DATAPULSE 100A pulse generator at a repetition rate of 1 kHz.

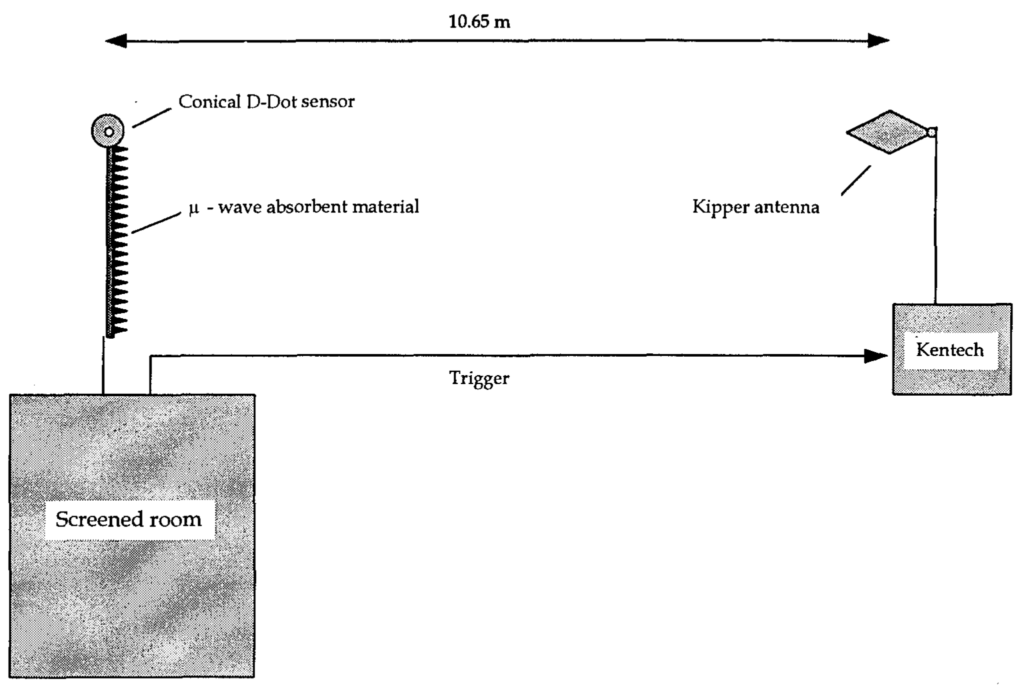

Figure 2.1: Plan view of experimental apparatus and setup.

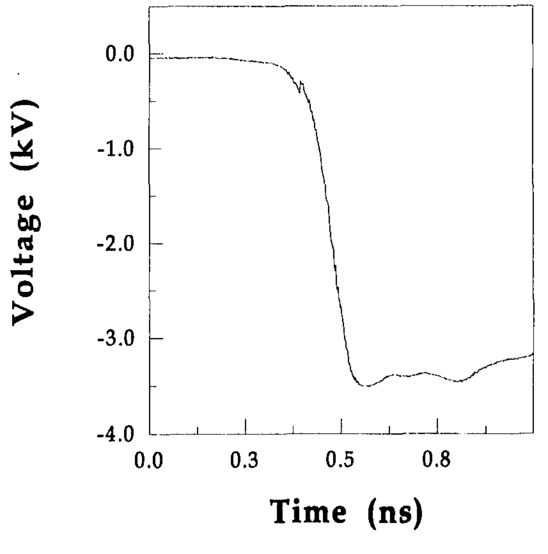

Figure 2.2: Kentech HMP 1 output voltage waveform.

For each different ground plane the sensor was rotated about a horizontal axis perpendicular to the boresight direction of the antenna. At a number of angles θ the voltage received on the sensor was recorded using a Tektronix TDS 820 digitising oscilloscope housed inside a screened room. Results for both positive angles (ie. where the conical monopole is on the same side of the ground plane as the antenna) and negative angles (ie. where the conical monopole is on the opposite side of the ground plane with respect to the antenna) were collected. Figure 2.3 shows one such typical voltage measurement.

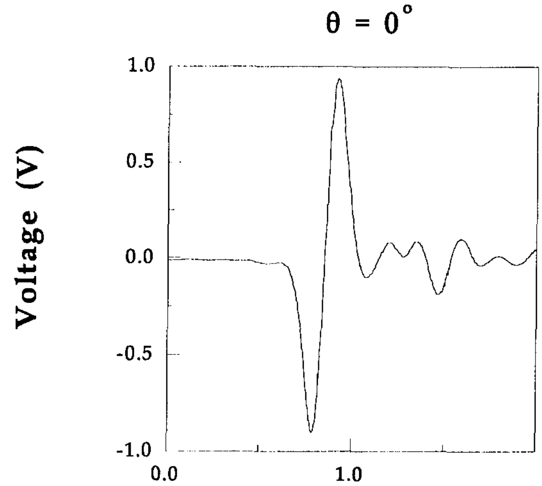

Figure 2.3: Measured sensor waveform for ***200 mm*** *diameter ground plane.*

Note that the probe signals were not corrected for cable losses in these experiments. While these losses do have a significant effect on the higher frequency components of the incident pulse, this effect does not influence the qualitative conclusions drawn from these measurements.

2.2 Results and discussion

The incident electric field E_{inc} for an ideal small conical monopole on an infinite ground plane is easily related to the received voltage V_{rec} by [3],

$$E_{inc} = \frac{2c}{3a^2 \cos\theta_0} \int V_{rec}\, dt$$

where c is the velocity of light, a = 9 mm is the radius of the cone and $\theta_0 = 47^o$ is the cone half angle (c.f Figure 1.1). For the D-dot sensors used the values for a and θ_0 were 9 mm and 47° respectively.

Assuming this formula to be valid, the electric fields, at the various angles θ, were reconstructed from the probe signals. Examples of these results can be seen in Figures 2.4 - 2.6 for the different ground plane sizes of 200 mm, 400 mm, and 600 mm diameters. Note that these dimensions were typical of ground planes used for this application.

At θ = 0° the reconstructed fields, for all three ground planes, are of approximately the same strength and have the expected Gaussian waveform. However, for angles other than zero the reconstructed fields vary considerably from the ideal both in shape and magnitude. In particular, for the ideal sensor both analytical and numerical calculations predict the strength of the detected field to be simply proportional to cos θ [2], [3]. This is definitely not the case for the current data.

The significant strength of the probe signals at negative values of θ would indicate that diffraction effects with the finite planes are important. Ideally for an infinite ground plane (or more realistically a very large finite plane) the incident field should be zero at those angles.

Note for negative angles of incidence, with the electric field incident from below the ground plane, the positive peak following the main negative pulse is the reflection from the trailing end of the ground plane. This reflection occurs at a time t after the main pulse given by,

$$t = \frac{2r_g}{c}\cos\theta$$

where r_g is the radius of the ground plane and c is the velocity of light. Note that the magnitude of this reflection is zero for θ = 0°.

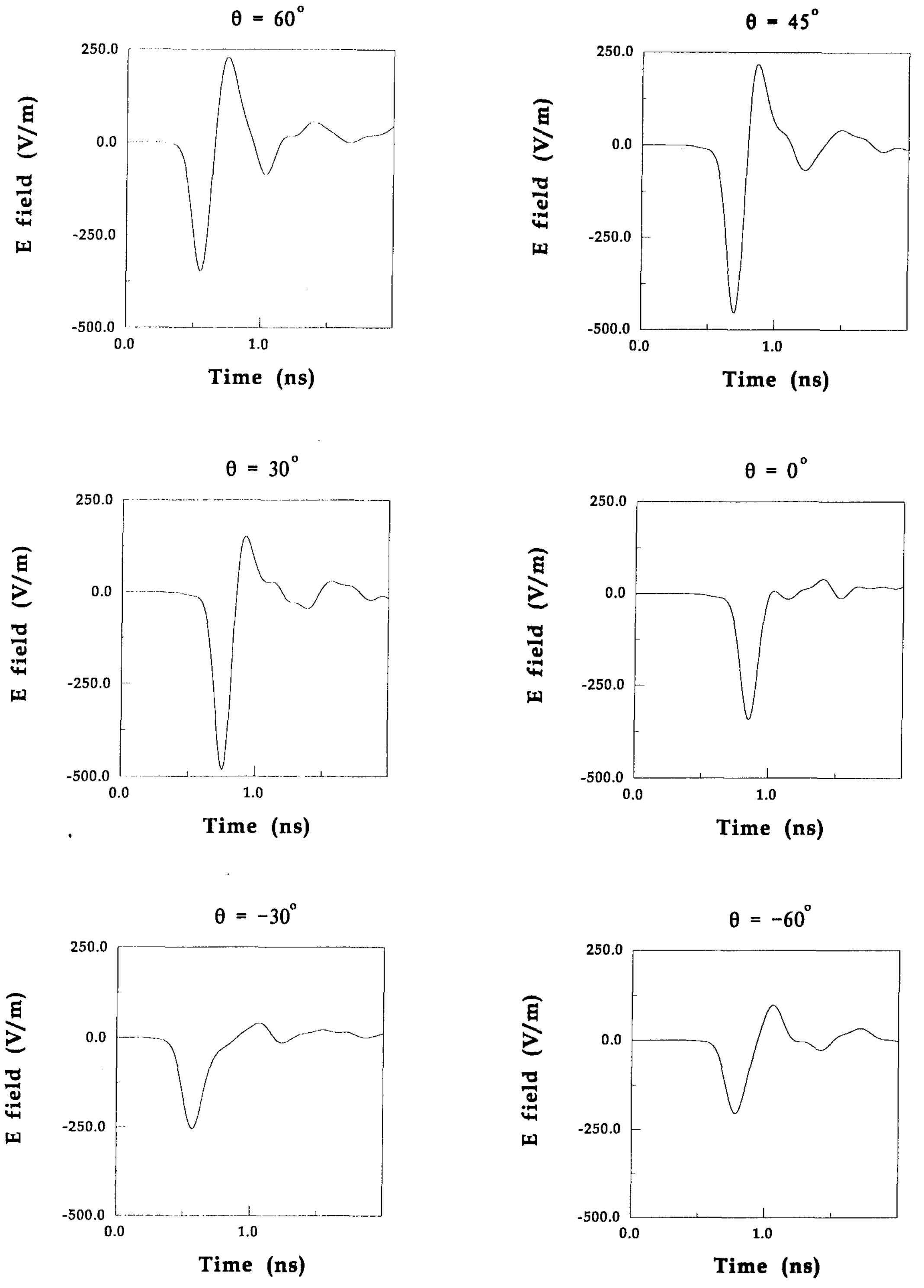

Figure 2.4: Reconstructed electric fields for ***200 mm*** *diameter ground plane.*

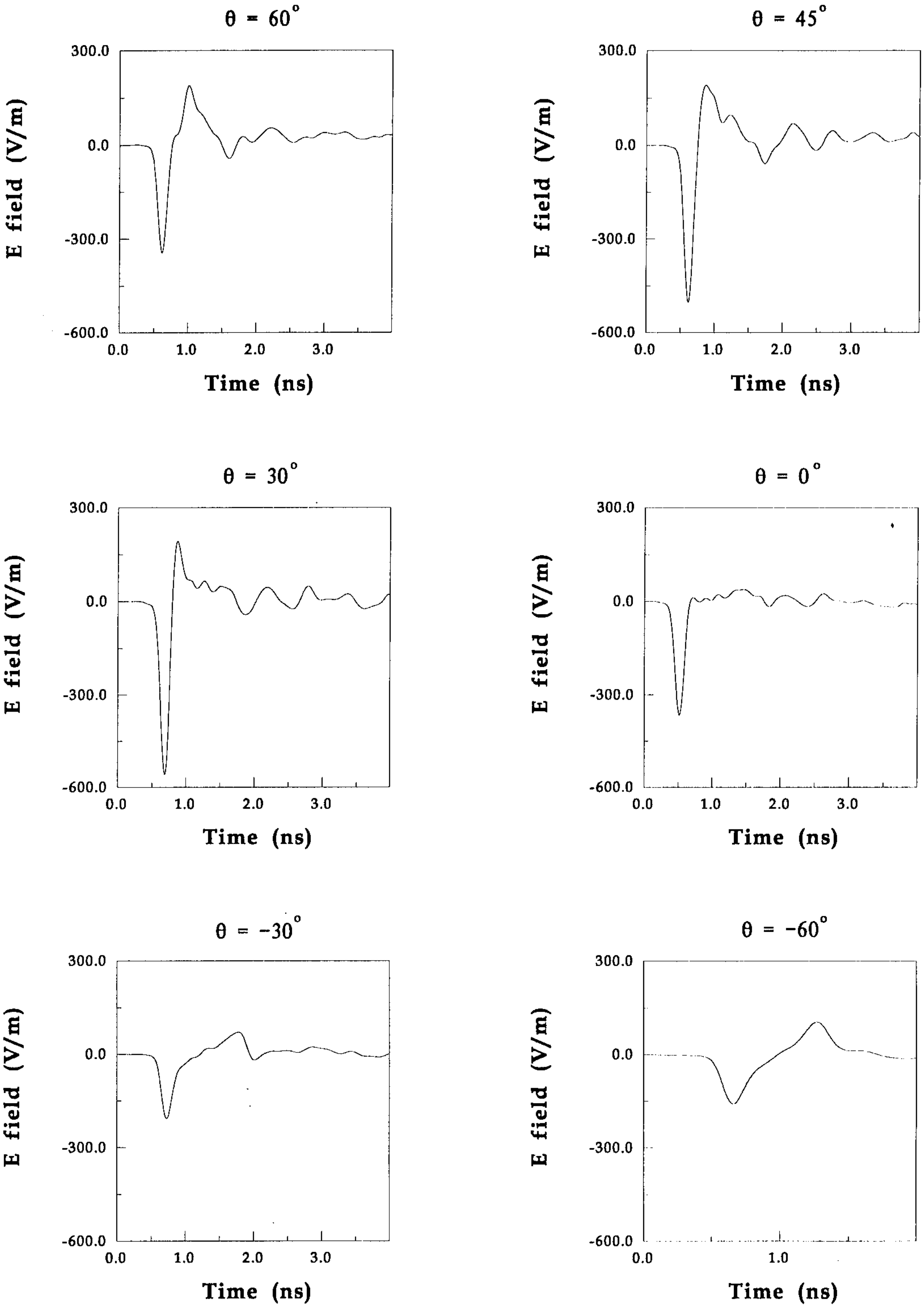

*Figure 2.5: Reconstructed electric fields for **400 mm** diameter ground plane.*

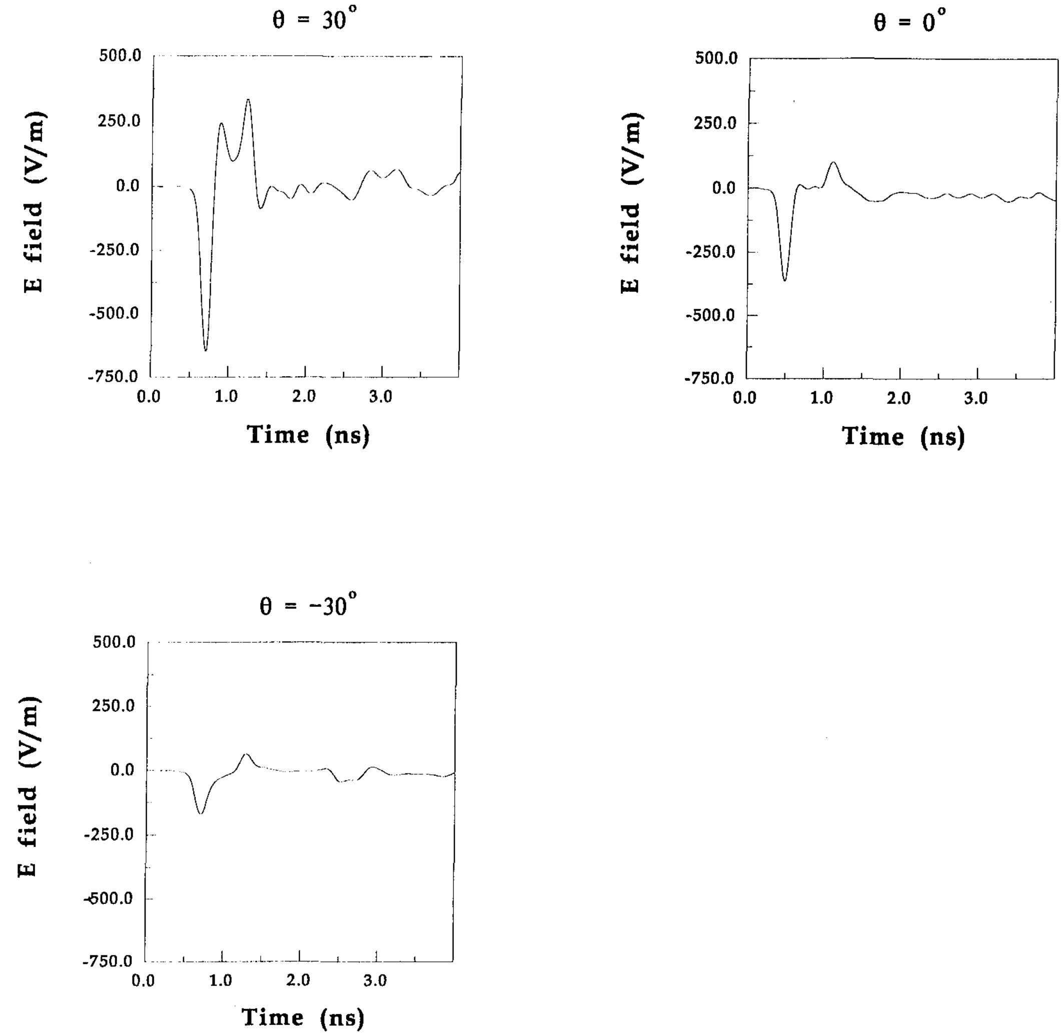

*Figure 2.6: Reconstructed electric fields for **600 mm** diameter ground plane.*

The effect of the ground plane size on the reconstructed fields can be gauged in Figure 2.7, where the peak magnitude of the main pulse has been plotted against θ. It can be clearly seen that increasing the size of the ground plane reduces the strength of the diffracted field for the negative angles of incidence. However, this also has the effect of significantly increasing the signal at positive angles, notably at around 30° for all cases.

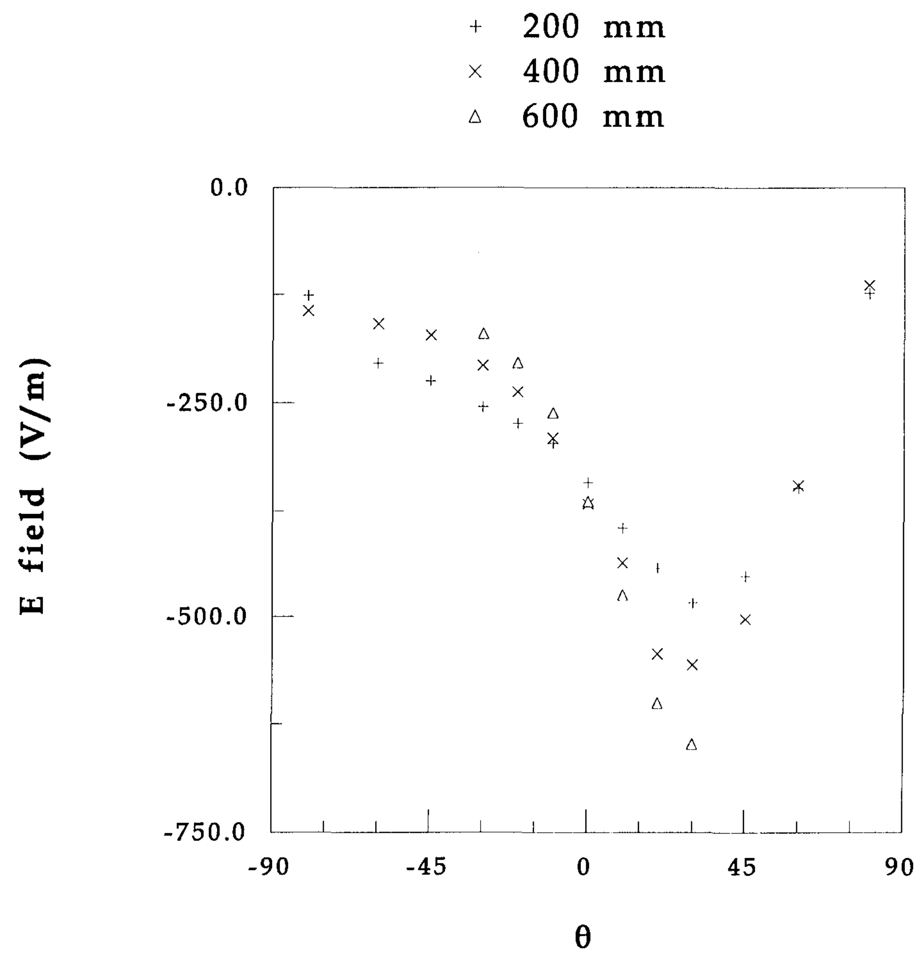

Figure 2.7: Peak incident electric field as a function of θ for different sized ground planes.

3. Conclusions

The present experimental measurements indicate that the response of the D-dot sensor for electric fields of non-zero angles of incidence to the ground plane is significantly affected by the use of a small ground plane. Electric fields incident on the probe from below the ground plane were found to produce reasonably large voltages on the D-dot probe, as opposed to the case of an infinite ground plane where obviously no signal would be expected. For electric fields incident from below the ground plane, increasing the size of the ground plane was found to reduce the D-dot probe signal. However, electric fields incident from above the ground plane were consistently overestimated, with the discrepancy from the ideal response progressively worsening for increasing ground plane size. For electric fields normal to the ground plane, the D-dot probe response agreed with the ideal case of an infinite ground plane as expected, since diffractive effects would be negligible.

Therefore, for measurements of electric fields which are expected to be incident along the ground plane, such as the direct radiation from antennas or scattering from small targets, the ground plane should be as large as practicable to reduce ground reflections and other extraneous signals originating from below the target.

The results shown in Figures 2.4 - 2.6 and summarised in Figure 2.7 indicate that for practical situations where the electric field to be measured is likely to be incident from large angles either above or below the ground plane, a small ground plane of diameter 200 mm or less is the optimum choice. In this case, the measured probe signal can be used to approximately determine the magnitude of the electric field within 50% of the true value for a 200 mm diameter ground plane. Note that the probe does not simply measure the electric field component normal to the ground plane. This conclusion is somewhat at odds with common sense which suggests that a large ground plane will best represent the ideal case of an infinite ground plane in all practical situations.

The predicted shape of the electric field was also found to vary for non-zero angles of incidence, with the appearance of extra non-physical peaks in the predicted field waveforms. This effect, combined with the variation in the predicted magnitude of the incident field at non-zero angles of incidence considerably complicates interpretation of the D-dot signal under these conditions. Figures 2.4-2.6 indicate that decreasing the size of the ground plane increases the distortion of the incident pulse measurement. Therefore, where a small ground plane should be used to most accurately determine the magnitude of the field, a large ground plane should be used to determine the shape of the incident field pulse.

This short study has demonstrated that the measurement of electric fields at non-zero angles of incidence will be unavoidably inaccurate and difficult to interpret using D-dot sensors on small ground planes, and should be avoided where possible. This can be done by measuring the field close to conducting surfaces, where the electric field direction can be readily deduced.

4. References

[1] Parkes, D. M. and Smith, P. D., "Practical method of predicting transient fields and monopole current waveforms", *IEE Proceedings*, Vol. 135, Pt. H No. 4, August 1988 pp 231-246.

[2] Staines, G. W. and Braidwood, S. W., "A Finite Difference Time Domain Calculation for Rotationally Symmetric Ultrawideband Antennas", DSTO-RR-0019, February 1995.

[3] Harrison, C. W. and Williams, C. S., "Transients in Wide-Angle Conical Antennas", *IEEE Transactions on Antennas and Propagation*, Vol. AP-13 No. 3, March 1965 pp 236-246.

THIS PAGE INTENTIONALLY BLANK

The Effect of Small Ground Planes on 9 mm Conical Monopole D-Dot Sensor Response

Sean Braidwood and Geoff Staines

(DSTO-GD-0047)

DISTRIBUTION

	Number of Copies
DEPARTMENT OF DEFENCE	
Defence Science and Technology Organisation	
Chief Defence Scientist and members of the	) 1 shared copy
DSTO Central Office Executive	) for circulation
Counsellor Defence Science, London	Doc Control Data Sheet Only
Counsellor Defence Science, Washington	Doc Control Data Sheet Only
Scientific Adviser POLCOM	1
Senior Defence Scientific Adviser	1
Assistant Secretary Scientific Analysis	1
Director, Aeronautical and Maritime Research Laboratory	1
Defence Intelligence Organisation	
Director, Scientific Analysis Branch Att. Head, Electronics	1
Electronics and Surveillance Research Laboratory	
Chief, Electronic Warfare Division	1
Research Leader, Electronic Countermeasures	1
Head, Advanced Concepts Group	1
Dr. Bevan Bates, Advanced Concepts Group	1
Dr. Geoff Staines, Advanced Concepts Group	1
Mr. Sean Braidwood, Advanced Concepts Group	1
HQADF	
Director, Directorate of Communications Engineering	1
Director General, Force Development (Sea)	1
Director General, Force Development (Land)	1
Director General, Force Development (Air)	1
Director General, Force Development (Joint)	1
Navy Office	
Navy Scientific Adviser	1
Army Office	
Scientific Adviser - Army	1

Air Office	
Air Force Scientific Adviser	1
Libraries and Information Services	
Defence Central Library, Technical Reports Centre	1
Manager, Document Exchange Centre (for retention)	1
National Technical Information Services, United States	2
Defence Research Information Centre, United Kingdom	2
DRA Malvern, United Kingdom Att. Mr. D. M. Parkes	1
Defence Science and Technology Organisation Salisbury, Research Library	2
Library Defence Signals Directorate, Canberra	1
Spares, DSTOS, Research Library	6

Department of Defence

DOCUMENT CONTROL DATA SHEET

1. Page Classification
UNCLASSIFIED
2. Privacy Marking/Caveat

3a. AR Number	3b. Establishment Number	3c. Type of Report	4. Task Number
AR-009-239	DSTO-GD-0047	GENERAL DOCUMENT	ADF 93/284

5. Document Date	6. Cost Code	7. Security Classification	8. No. of Pages	9. No. of Refs.
MARCH 1995	839262	L U U (Document Title Abstract)	22	3

7. Security Classification: L (Document), U (Title), U (Abstract)

S (Secret C (Confi) R (Rest) U (Unclass)

* For UNCLASSIFIED docs with a secondary distribution LIMITATION, use (L) in document box.

10. Title
THE EFFECT OF SMALL GROUND PLANES ON 9 MM CONICAL MONOPOLE D-DOT SENSOR RESPONSE

11. Author(s)
Sean Braidwood
Geoff Staines

12. Downgrading/ Delimiting Instructions
Limitation to be reviewed in March 2000

13a. Corporate Author and Address
Electronic Warfare Division
Electronics and Surveillance Research Laboratory
PO Box 1500 SALISBURY SA 5108

13b. Task Sponsor
HQADF

14. Officer/Position responsible for

Security	SOESRL
Downgrading	CEWD
Approval for release	CEWD

15. Secondary Release Statement of this Document

Access additional to the initial distribution list is limited to the Defence Organisation of Australia, USA and UK. Others MUST be referred to Chief, Electronic Warfare Division, ESRL.

Any enquiries outside stated limitations should be referred through DSTIC, Defence Information Services, Department of Defence, Anzac Park West, Canberra, ACT 2600.

16a. Deliberate Announcement

May be announced to the Defence Organisation of Australia, UK and USA.

16b. Casual Announcement (for citation in other documents)

[√] No Limitation | [ ] Ref. by Author, Doc No and date only

17. DEFTEST Descriptors
Electrical Measurement
Electric Fields
Antenna Radiation Patterns
Sense Antennas
Monopole Antennas

18. DISCAT Subject Codes

19. Abstract

The effect of small ground planes on the response of a 9 mm conical monopole electric field sensor was studied experimentally for fields incident from various angles to the ground plane. This short study was undertaken to investigate the consequences of ground plane diffraction for 200 mm, 400 mm, and 600 mm diameter ground planes. These diameters are typical of those used for practical measurements. Qualitative assessments are made of the effects on the shape and amplitude of the measured pulse and the implications for practical electric field measurements.

ADB200116

DEPARTMENT OF DEFENCE
DEFENCE SCIENCE & TECHNOLOGY ORGANISATION
DSTO

SCIENCE CORPORATE MANAGEMENT BRANCH
DSTO RESEARCH LIBRARY-REPORTS DISTRIBUTION
PO BOX 1500 EDINBURGH SA 5111

Reference: R9607/7/9 Pt4 Folio No.81
Contact: Natalie Mahlknecht
E-mail: Natalie.Mahlknecht@dsto.defence.gov.au

Telephone: (08) 8259 6255
Facsimile: (08) 8259 6803

Tuesday, 26 March 2002

To All Copyholders
cc: To the Team Leader of Records & Archives

Notification of Downgrading/ Delimiting of DSTO Report

Please note that the Release Authority has authorised the downgrading/ delimiting of the report detailed here:

DSTO NUMBER	**DSTO-GD-0047**
AR NUMBER	**AR-009-239**
FILE NUMBER	**Unknown**
PREVIOUS Classification	**WAS:-** LIMITED RELEASE
REVISED Classification and Release Limitation	UNCLASSIFIED **Public Release** **NO LIMITATIONS**

Please amend your records and make changes to your copy of the report itself to reflect the new classification/ release limitation.

Mrs. Natalie Mahlknecht
Reports Distribution Officer
DSTO Research Library, Edinburgh